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# ANALYSIS OF STRATIGRAPHIC POLLEN AND PHYTOLITH SAMPLES FROM RIO DEL OSO, NEW MEXICO

By

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## INTRODUCTION

Several stratigraphic columns were sampled in the cut bank at Rio del Oso to recover pollen and phytoliths that will provide a signal of regional and local vegetation through time. This vegetation is expected to be a reflection of both natural and cultural events. Radiocarbon ages are available for many levels, providing tight dating for the stratigraphic columns. The pollen record was examined to provide evidence of changes in both regional and local vegetation, while the phytolith record was expected to provide a record of changes in the local grass population and perhaps evidence of other plants. Microscopic charcoal was tallied to provide information concerning regional fires during times represented. The goal of this analysis is reconstruction of past vegetation and vegetation communities, leading to an interpretation of the paleoenvironment and a reconstruction of the landscape.

## METHODS

### Pollen 1996

A chemical extraction technique based on flotation is the standard preparation technique used in this laboratory for the removal of the pollen from the large volume of sand, silt, and clay with which they are mixed. This particular process was developed for extraction of pollen from soils where preservation has been less than ideal and pollen density is low.

Hydrochloric acid (10%) was used to remove calcium carbonates present in the soil, after which the samples were screened through 150 micron mesh. The samples were rinsed until neutral by adding water, letting the samples stand for 2 hours, then pouring off the supernatant. A small quantity of sodium hexametaphosphate was added to each sample once it reached neutrality, then the beaker was again filled with water and allowed to stand for 2 hours. The samples were again rinsed until neutral, filling the beakers only with water. This step was added to remove clay prior to heavy liquid separation. At this time the samples are dried then pulverized. Zinc bromide (density 2.1) was used for the flotation process. The samples were mixed with zinc bromide and centrifuged at 1500 rpm for 10 minutes to separate organic from inorganic remains. The supernatant containing pollen and organic remains is decanted and diluted. Zinc bromide is again added to the inorganic fraction to repeat the separation process. After rinsing the pollen-rich organic fraction obtained by this separation, all samples received a short (20 minute) treatment in hot hydrofluoric acid to remove any remaining inorganic particles. The samples were then acetolated for 3 minutes to remove any extraneous organic matter.

A light microscope was used to count the pollen to a total of 400 pollen grains at a magnification of 400-600x. Pollen preservation in these samples varied from good to poor. Comparative reference material collected at the Intermountain Herbarium at Utah State University and the University of Colorado Herbarium was used to identify the pollen to the family, genus, and species level, where possible.

Pollen aggregates were recorded during identification of the pollen. Aggregates are clumps of a single type of pollen, and may be interpreted to represent pollen dispersal over short distances, or the introduction of portions of the plant represented into an archaeological setting. Aggregates were included in the pollen counts as single grains, as is customary. The presence of aggregates is noted by an "A" next to the pollen frequency on the pollen diagram. A plus (+) on the pollen diagram indicates that the pollen type was observed outside the regular count while scanning the remainder of the microscope slide.

Indeterminate pollen includes pollen grains that are folded, mutilated, and otherwise distorted beyond recognition. These grains are included in the total pollen count, as they are part of the pollen record.

## Pollen 2000

A chemical extraction technique based on flotation is the standard preparation technique used in this laboratory for the removal of the pollen from the large volume of sand, silt, and clay with which they are mixed. This particular process was developed for extraction of pollen from soils where preservation has been less than ideal and pollen density is low.

Hydrochloric acid (10%) was used to remove calcium carbonates present in the soil, after which the samples were screened through 150 micron mesh. The samples were rinsed until neutral by adding water, letting the samples stand for 2 hours, then pouring off the supernatant. A small quantity of sodium hexametaphosphate was added to each sample once it reached neutrality, then the beaker was again filled with water and allowed to stand for 2 hours. The samples were again rinsed until neutral, filling the beakers only with water. This step was added to remove clay prior to heavy liquid separation. At this time the samples are dried then pulverized. Sodium polytungstate (density 2.1) was used for the flotation process. The samples were mixed with sodium polytungstate and centrifuged at 2000 rpm for 5 minutes to separate organic from inorganic remains. The supernatant containing pollen and organic remains is decanted. Sodium polytungstate is again added to the inorganic fraction to repeat the separation process. The supernatant is decanted into the same tube as the supernatant from the first separation. This supernatant is then centrifuged at 2000 rpm for 5 minutes to allow any silica remaining to be separated from the organics. Following this, the supernatant is decanted into a 50 ml conical tube and diluted with distilled water. These samples are centrifuged at 3000 rpm to concentrate the organic fraction in the bottom of the tube. After rinsing the pollen-rich organic fraction obtained by this separation, all samples received a short (10-15 minute) treatment in hot hydrofluoric acid to remove any remaining inorganic particles. The samples were then acetolated for 3 minutes to remove any extraneous organic matter.

A light microscope was used to count the pollen to a total of 100 to 200 pollen grains at a magnification of 400-600x. Pollen preservation in these samples varied from good to poor. Comparative reference material collected at the Intermountain Herbarium at Utah State University and the University of Colorado Herbarium was used to identify the pollen to the family, genus, and species level, where possible.

Pollen aggregates were recorded during identification of the pollen. Aggregates are clumps of a single type of pollen, and may be interpreted to represent pollen dispersal over short distances, or the introduction of portions of the plant represented into an archaeological setting. Aggregates were included in the pollen counts as single grains, as is customary. The presence of aggregates is noted by an "A" next to the pollen frequency on the pollen diagram. A plus (+) on the pollen diagram indicates that the pollen type was observed outside the regular count while scanning the remainder of the microscope slide. Pollen diagrams are produced using Tilia, which was developed by Dr. Eric Grimm of the Illinois State Museum. Pollen concentrations are calculated in Tilia using the quantity of sample processed, the quantity of exotics (spores) added to the sample, the quantity of exotics counted, and the total pollen counted. Exaggerations of pollen frequencies are calculated within the diagraming program. Tilia was used to produce all pollen and phytolith diagrams in this study.

Indeterminate pollen includes pollen grains that are folded, mutilated, and otherwise distorted beyond recognition. These grains are included in the total pollen count, as they are part of the pollen record.

## Phytoliths 1997

Extraction of phytoliths from these sediments also was based on heavy liquid floatation. Approximately 50 ml of sediment was added to 50 ml of sodium hexametaphosphate (0.1 molar solution) to suspend the clays. The sample was then sieved through 150 micron mesh. The sample was allowed to settle for two hours, then the supernatant was poured off, which contained clay. This settling time allowed the phytoliths to settle to the base of the beaker. The samples were mixed with water, allowed to settle for two hours, and the supernatant discarded several times, until the supernatant was clear. Liquid bleach was added to the sample and allowed to sit overnight to destroy the organic fraction in the sample. Rinses were continued to remove the bleach, then the remaining clays. The last two times the sample is allowed to settle the time is reduced to one hour. This procedure removes most of the clays. Once most of the clays were removed, the silt and sand size fraction was dried. The dried silts and sands were then mixed with zinc bromide (density 2.3) and centrifuged to separate the phytoliths, which will float, from the other silica, which will not. Phytoliths, in the broader sense, may include opal phytoliths and calcium oxalate crystals. Calcium oxalate crystals are formed by *Opuntia* (prickly pear cactus), and are separated, rather than destroyed, using this extraction technique, since it employs no acids. If calcium carbonates are present, use of glacial acetic may be employed to dissolve the calcium carbonates without destroying any calcium oxalates present. Any remaining clay is floated with the phytoliths, and is further removed by mixing with sodium pyrophosphate and distilled water. The samples are then rinsed with distilled water, then alcohols to remove the water. After several alcohol rinses, the samples are mounted in Cinnamaldehyde for counting with a light microscope at a magnification of 500x.

## Phytoliths 2000

Extraction of phytoliths from these sediments also was based on heavy liquid floatation. Sodium hypochlorite (bleach) was first used to destroy the organic fraction from 50 ml of sediment. Once this reaction was complete, calgon was added to the mixture to suspend the clays. The sample was rinsed thoroughly with distilled water to remove the clays, allowing the samples to settle by gravity. Once most of the clays were removed, the silt and sand size fraction was dried. The dried silts and sands were then mixed with sodium polytungstate (density 2.3) and centrifuged to separate the phytoliths, which will float, from the other silica, which will not. Phytoliths, in the broader sense, may include opal phytoliths and calcium oxalate crystals. Calcium oxalate crystals are formed by *Opuntia* (prickly pear cactus) and other plants including *Yucca*, and are separated, rather than destroyed, using this extraction technique, if these forms have survived in the sediments. Any remaining clay is floated with the phytoliths, and is further removed by mixing with calgon and distilled water. The samples are then rinsed with distilled water, then alcohols to remove the water. After several alcohol rinses, the samples are mounted in cinnamaldehyde for counting with a light microscope at a magnification of 500x. Phytolith diagrams are produced using Tilia, which was developed by Dr. Eric Grimm of the Illinois State Museum for diagraming pollen.

## PHYTOLITH REVIEW

Phytoliths are silica bodies produced by plants when soluble silica in the ground water is absorbed by the roots and carried up to the plant via the vascular system. Evaporation and metabolism of this water result in precipitation of the silica in and around the cellular walls. The general term phytoliths, while strictly applied to opal phytoliths, may also be used to refer to calcium oxalate crystals produced by a variety of plants, including *Opuntia* (prickly pear cactus). Unfortunately, calcium oxalate crystals do not appear to preserve in most sediments. Opal phytoliths, which are distinct and decay-resistant plant remains, are deposited in the soil as the plant or plant parts die and break down. They are, however, subject to mechanical breakage and erosion and deterioration in high pH soils. Phytoliths are usually introduced directly into the soils

in which the plants decay. Transportation of phytoliths occurs primarily by animal consumption, man's gathering of plants, or by erosion or transportation of the soil by wind, water, or ice.

The major divisions of grass short-cell phytoliths recovered include festucoid, chloridoid, and panicoid. Smooth elongate phytoliths are currently of no aid in interpreting either paleoenvironmental conditions or the subsistence record because they are produced by a large number of grasses. Phytoliths tabulated to represent "total phytoliths" include all forms representing plants. Frequencies for all other bodies recovered are calculated by dividing the number of each type recovered by the "total phytoliths".

The festucoid class of phytoliths is ascribed primarily to the subfamily Pooideae and occur most abundantly in cool, moist climates. However, Brown (1984) notes that festucoid phytoliths are produced in small quantity by nearly all grasses. Therefore, while they are typical phytoliths produced by the subfamily Pooideae, they are not exclusive to this subfamily. Chloridoid phytoliths are found primarily in the subfamily Chloridoideae, a warm-season grass that grows in arid to semi-arid areas and require less available soil moisture. Chloridoid grasses are the most abundant in the American Southwest (Gould and Shaw 1983:120). Panicoid phytoliths occur in warm-season or tall grasses that frequently thrive in humid conditions. Twiss (1987:181) also notes that some members of the subfamily Chloridoideae produce both bilobate (panicoid) and festucoid phytoliths. "According to Gould and Shaw (1983, p. 110) more than 97% of the native US grass species (1,026 or 1,053) are divided equally among three subfamilies Pooideae, Chloridoideae, and Panicoideae" (Twiss 1987:181).

Buliform phytoliths are produced by grasses in response to wet conditions (Irwin Rovner, personal communication, January 1991), and are to be expected in wet habitats of floodplains and other places. Trichomes and papilla represent epidermal hairs on grasses and/or sedges. Epidermal forms represent epidermal cells, probably of dicotyledenous plants.

Diatoms and sponge spicules were also noted. Diatoms, in general, indicate wet conditions, at least in a specific econiche. Sponge spicules probably represent fresh water sponges that live in rivers. Their recovery in upland soils in Illinois is noted to accompany loess deposits derived from floodplains (Jones and Beavers 1963).

Volcanic ash fragments are noted to be widely dispersed in sediments across the North American continent in quantities varying from mere presence to dominance of the record. At present, volcanic ash fragments are interpreted to represent tiny fragments present in the upper atmosphere that fall to the earth, rather than any specific volcanic event.

## DISCUSSION

Stratigraphic samples were collected from three areas, yielding Profiles A, B, and C, in the cut bank along Rio del Oso in northern New Mexico to provide pollen and phytolith records of prehistoric vegetation. In addition, seven modern vegetation plots were examined to provide modern analogs for working with the past vegetation record. Radiocarbon ages place the base of this record near 4000 BP. Single samples were collected for each of the strata identified in the field. Budgetary constraints prevented sampling at closer intervals. Extended pollen and phytolith counts of 400+ grains were obtained for most of the samples, providing a robust data base. Exceptions include phytolith samples 6, 7, 8, and 9 from Profile A (the original cut bank), which contained very few phytoliths and pollen samples 16 and 17 near the base of Profile B, which did not yield sufficient pollen to reach a 400 grain count. It is likely that recovery of only a few phytoliths from these levels is the result of a paucity of local vegetation, particularly grasses, or of rapid deposition combined with a reduction in grasses, and provides a valuable interpretation. In the pollen record, pollen concentrations dropped below 4 pollen per cc of sediment and were recorded as 3 and 1 pollen per cc of sediment, respectively for samples 16 and 17. Even these

very low pollen densities yielded over 200 pollen grain counts, which would be statistically acceptable if all of the pollen recovered had been ancient. Instead, portions of the pollen records in samples 15, 16, and 17, all of which have low pollen densities, include modern pollen probably introduced at the time of sampling, meaning that it is not appropriate to interpret these records for any information concerning past vegetation. In pollen sample 15 all of the *Elaeagnus* pollen was modern, although there was little other pollen that appeared to be modern in this sample. Samples 16 and 17 both contained significant quantities of modern *Artemisia*, Low-spine Asteraceae, and *Pinus* pollen.

The pollen record may be divided into zones based on cluster analysis performed by the Tilia computer pollen diagraming program. This statistical analysis of the data also indicates relationships between the various pollen zones. The same technique is used with the phytolith records to create phytolith zones. Phytolith frequencies are based on total grass short cells (festucoid, chloridoid, and panicoid). Other phytoliths are calculated relative to this total, which allows a closer comparison of the grass populations. Grass short cells are the only phytoliths that can be used to define the distinction between festucoid (cool season), chloridoid (short), and panicoid (tall) grasses.

## Modern Vegetation Plots

The pollen record from seven samples collected from modern vegetation plots exhibits significant variations. The blue grama grassland with some oak, juniper with blue grama, and juniper with some pinyon vegetation plots were sampled in two different locations. A single location of riparian vegetation with cottonwood, willows, and juniper was sampled only in a single location. The pollen diagram is ordered to reflect samples of similar vegetation plots next to each other. Visually, pollen samples from blue grama grasslands are most like each other; samples from juniper with blue grama grass display similarities to one another; and samples from juniper with some pinyon resemble each other. The characteristics of samples collected in blue grama grassland containing some oak (P1V1 and P2V1) include moderately small quantities of *Juniperus* and *Pinus* pollen frequencies (Figure 1, Table 2), slightly elevated *Quercus* pollen frequencies, and elevated *Artemisia* and Poaceae pollen frequencies. Pollen concentrations are moderate (approximately 17,000 to 25,000 pollen per cc of sediment). Samples P1V2 and P2V2 represent juniper with some blue grama grass. These samples exhibit slightly elevated *Juniperus* and *Pinus* pollen frequencies when compared with the blue grama grassland samples. In addition, High-spine Asteraceae and Cheno-am pollen frequencies are elevated, while *Artemisia* and Poaceae pollen frequencies are depressed. Pollen concentrations are high at approximately 50,000 pollen per cc. Pollen representing juniper with some pinyon habitats (P1V3 and P2V3) exhibit even more highly elevated *Juniperus* and *Pinus* pollen frequencies, with the change in *Juniperus* pollen being most evident. In addition, quantities of *Artemisia* and Cheno-am pollen are quite low. Although the quantity of High-spine Asteraceae pollen is lower than that recorded in most other habitats, it is not the lowest observed in the modern vegetation plots. Quantities of Poaceae pollen, though, are the lowest observed. Pollen concentrations vary greatly between approximately 10,000 and approximately 50,000 pollen per cc of sediment. A single sample was examined from a riparian vegetation community (P1V4). This sample yielded an elevated *Pinus* pollen frequency, but moderate *Juniperus* pollen frequency. Interestingly, the quantity of *Quercus* pollen was highest in this sample of all the samples examined. In addition, both *Populus* and *Salix* pollen were observed in this sample. Only small quantities of *Artemisia*, High-spine, Cheno-am, and a variety of other pollen types were observed. The Poaceae pollen frequency was moderate. This sample exhibited the most varied pollen assemblage of all samples examined, including evidence for Fabaceae, *Petalostemon*, *Portulaca*, *Rhus toxicodendron*, Rosaceae striate, and *Elaeagnus* pollen, the latter of which represents a plant introduced during the historic era. The quantity of microcharcoal is largest in sample P1V4, collected from the riparian habitat. Microcharcoal was not particularly abundant in any of the other modern vegetation plot samples.

The phytolith record from the modern vegetation plots yields evidence that short grasses dominate all of the vegetation plots. This dominance is less obvious in sample P1V4, collected from the riparian habitat, as expected. The increased moisture and shade inherent in sediments of a riparian habitat are expressed in an increase of festucoid phytoliths (Figure 2). The quantity of buliforms recovered in this sample is surprisingly low. It is interesting to note that the largest quantity of buliforms was observed in sample P1V2, collected in a juniper with blue grama habitat. Apparently the short grasses growing in this area received an adequate or more than adequate supply of moisture. Crenate and crescent forms are noticeably more abundant, as are circular forms, in this riparian sample.

Examination of pollen and phytoliths from modern vegetation plots is expected to provide a data base for interpreting the stratigraphic records examined from various profiles along the Rio del Oso.

## Profile A

Pollen zones 2 and 3 in Profile A display the most similarity to one another and as a group are most closely related to pollen zone 1. This places the most related groups of vegetation all prior to approximately 2000 years ago, probably prior to intensive human manipulation of the environment. This group of pollen zones is then related to the latest subsurface group of samples (zone 4). All of the subsurface zones differ substantially in pollen content from pollen zone 5, which is comprised only of modern surface samples.

The pollen diagram indicates greater *Artemisia* and Cheno-am (Figure 3) populations in the past than during the present, indicating that sagebrush and probably saltbush and related plants, were more abundant. The *Quercus* population appears to have been largest during pollen zone 3, particularly at the base of this zone, suggesting an abundance of Gambel's oak, probably growing as local thickets along the Rio del Oso. Pollen zone 2 exhibits the largest *Pinus* pollen frequencies. Pollen zone 2 also includes samples 6-9, which contained very few phytoliths, suggesting a paucity of local vegetation. One possible reason for an increase in *Pinus* pollen frequencies is a reduced production of pollen by local vegetation. If local vegetation is less dense and growing under stressed conditions, it will not produce as much pollen as it could under better growing conditions. At times like this, when local pollen production declines, there is an apparent increase in pollen that travels well on the wind, such as *Pinus*. It is interesting to note that *Juniperus* pollen, which also is transported on the wind, is slightly elevated in this zone. *Pseudotsuga* pollen is slightly elevated, occurring in all samples from this zone. *Rhus trilobata* pollen is elevated in this zone, indicating the presence of increased quantities of lemonade berry shrubs. Cheno-am pollen is noted in low frequencies at the base of this zone, increasing steadily and slowly towards the top of the zone. The uppermost sample might represent a stable surface since the pollen concentration is much larger in this sample. The most likely interpretation of this zone is that sediments accumulated rapidly during the spring or early summer, perhaps as a result of flooding.

Total pollen concentrations often correlate with depositional conditions. Higher total pollen concentrations are expected in modern samples that have not undergone pollen degradation. Pollen is subject to attack by micro-organisms in the soil, mechanical abrasion, and oxidation. As pollen decays, total pollen concentration should decrease. Some factors act either to preserve more pollen or to concentrate pollen in sediments, resulting in increased pollen densities. A-horizons usually form slowly and often reflect a relatively stable surface that aggraded slowly. When this is true, pollen concentration in the A-horizon is expected to be very large. Pollen decays within this A-horizon, as it does in other layers, but larger quantities of pollen should remain even after decay. If decay is relatively uniform, the very large quantity of pollen originally present in the A-horizon is noted by elevated pollen concentrations in subsurface deposits. Probable A-horizons or stable surfaces are reflected in pollen samples 10, 11, and 17, and possibly also in samples 2, 4, and 5. In pollen zone 4 pollen concentrations are higher and with the exception of a upper few

samples, probably represent periods of stable land surfaces. Small quantities of pollen recovered in samples 1, 3, 6, 7, 9, and to a lesser extent in samples 12-16, and 21 might be associated with faster deposition of sediments.

A decrease in plant diversity is noted during pollen zone 3, and another decline in diversity in pollen zone 4. Plants that disappear from the pollen record in pollen zone 3 include *Portulaca*, Rhamnaceae, *Rhamnus*, *Rhus trilobata*, and Rosaceae. The majority of these plants are shrubs, with the exception of *Portulaca*. Failure to recover these pollen types in pollen zone 3 is a puzzle, since this pollen zone corresponds with probable intensification of human population. *Portulaca* should have been present as part of the weedy plant complex as human occupation increased. It is possible that shrubby plants growing along Rio del Oso were cleared, although some of these plants should have been valuable as food and/or medicinal resources. Plants that disappear from the record in pollen zone 4 include *Kallstroemia*-type, *Malva*, *Boerhaavia*-type, and *Mirabilis*. All of these plants are disturbance indicators. Again, disappearance of these plants from the pollen record at a time when human occupation is expected to have intensified again is puzzling.

Examining the pollen record for pollen that reflects plants that prefer specific habitats yields valuable information. Pollen representing plants that prefer riparian habitats is more abundant in pollen zones 4 and 5, with a moderate quantity recorded in pollen zone 3. Pollen zones 1 and 2 contain little pollen representing plants that prefer this habitat. Pollen representing seedy plants is most abundant in pollen zones 1 and 2, suggesting that natural disturbance to the landscape at a time when human population was not particularly large, was sufficient to sustain moderately large populations of weedy plants. Interestingly, as human population increased, these plants appear to have declined in quantity. This pattern of vegetation points to the need to assess human populations on the landscape throughout the earlier intervals represented in this record.

*Zea mays* pollen is an important part of the record. It occurs in samples 15, 16, and 17, representing the time interval between radiocarbon ages of 3010 and 3110 BP. Recovery of *Zea mays* pollen at this time indicates the presence of agriculture in the valley or even adjacent to Rio del Oso.

The micro-charcoal record exhibits its peak in sample 4, prior to BC 3515-3285/3245-3105. The quantity of micro-charcoal remained relatively high in sample 5, which yielded the above radiocarbon age. Although some changes are noted in the charcoal frequencies, with an increase noted at the same time as the presence of *Zea mays* pollen, reflecting active maize agriculture, it declines after this time. The smallest quantities of charcoal are noted in the modern surface samples.

The phytolith record is one of contrasting festucoid and chloridoid frequencies (Figure 4), representing cool season and short grasses, respectively. Festucoid or cool season grasses grow during the spring and fall when sufficient moisture is present. During mild winters these grasses also might grow. They become dormant during the summer, when short grasses flourish. Chloridoid or short grasses thrive in hot, dry weather, growing only during the heat of the summer and becoming dormant when conditions are too cold. Panicoid grasses, which are poorly represented here, are tall grasses that grow particularly well in hot weather with plenty of moisture. Maize is a member of the panicoid group of grasses. The bilobate forms noted in this record represent a relatively small population of panicoid or tall grasses.

The most related populations of grasses in the phytolith record are in Zones 1 and 2, which resemble each other, and in Zones 3 and 4, which resemble each other. The group of Zones 1 and 2 is quite different from the group of Zones 3 and 4, according to the cluster analysis performed by Tilia. Zones within the phytolith record are not identical to those defined within the pollen record. Both records define Zone 1 as including the lowest 5 samples and both the pollen and phytolith cluster analyses places samples 4 and 5 as closely related. Pollen concentrations and phytolith counts also indicate at least periodically stable surfaces. The grass population during this time appears to be relatively evenly divided between festucoid or cool season and chloridoid or short

grasses. This apparent even division is somewhat misleading because it probably reflects biomass rather than numbers of plants. Most cool season grasses are much larger than the short grasses. Therefore, it is likely that short grasses were more abundant in the landscape than were cool season grasses. Buliforms were moderately abundant, suggesting that the grasses growing in this area received sufficient moisture for their requirements. Trichomes also were moderately abundant, declining towards the top of this zone. These silicified hairs often grow more densely on the reproductive parts of grasses than the leaves, suggesting that flowering and seeding was abundant. This interpretation is consistent with grasses receiving sufficient moisture for good growth.

Phytolith Zone 2 includes samples with very low phytolith counts. Low counts in samples 6, 7, and 9 correspond to low pollen concentrations in these sample samples. The increased phytolith count in sample 8 corresponds to an increased pollen concentration. Therefore, the interpretation of rapid deposition is probably a valid one for the interval between samples 6 and 9, with the most stable surface represented by sample 8, which yielded a radiocarbon age of 4230 BP. The most abundant forms noted in these samples often are those forms that are quite robust, including buliforms, elongate smooth, and dicot bulky forms. This probably represents an environment of dissolving phytoliths within these sediments and should not be interpreted to represent environmental conditions or plant populations.

Phytolith Zone 3 is a large one exhibiting fluctuations in phytolith frequencies. Quantities of festucoid and chloridoid short cells fluctuate in opposition to one another in each of the samples in the lower portion of this record, suggesting changing conditions that support alternately larger and smaller populations of cool season and short grasses. More than one alternate interpretation may be made from this record including short interval deposition of large quantities of sediment as a result of flooding or deflation of the surface between each of these samples. The phytolith record becomes more stable with increasing quantities of chloridoid and decreasing quantities of festucoid phytoliths, culminating in extremes in sample 18. Most of this interval (samples 13 through 17) appears to represent a relatively short period of sediment accumulation between approximately 3140 and 3010 BP, a period that exhibits *Zea mays* pollen, indicating maize agriculture. The phytolith record suggests a period of an expanding warm growing season with the possibility that summers were quite hot and dry. An alternative interpretation is that the Rio del Oso was more incised during this time period, resulting in less water being available to the roots of the grasses growing here, thus exaggerating the signal of hot, dry conditions. Buliforms are much less abundant during this zone than in other parts of the record, confirming that plants growing here were not receiving as much water, possibly not an adequate supply for a healthy grass population. Dicot forms are present throughout this zone. Samples 18 and 19, which are separated from the other samples in this zone by approximately 1000 years, display evidence that cool season grasses were expanding and short grasses declining between approximately 2120 and 1710 BP.

Phytolith Zone 4 is relatively short, including only samples 20 through 24, representing sediments that have accumulated in the past approximately 1500 years. The trend in this portion of the phytolith record is of increasing chloridoid and declining festucoid frequencies, with the exception of the reversal in this trend in sample 24, representing a time interval approximately 640 BP. This record again suggests warming and drying conditions at least intermittently during the period between approximately 1530 and 730 BP. It is interesting to note that even though conditions appear to have been warming and drying that the quantity of buliforms is larger than that in Phytolith zone 3. Therefore, it is unlikely that conditions were so extreme that the grasses growing here did not receive sufficient moisture for adequate growth.

## Profile B

Pollen concentrations in Profile B are extremely high in some samples. Samples 13, 12, 11, 8, and 7, all exhibit very large pollen concentrations (Figure 5) for samples older than approximately 2000 years. In addition, samples 14, 6, and 5 contain moderate pollen

concentrations. Samples 4, 3, and 2 exhibit very large pollen concentrations and represent sediments that accumulated within the past 400 years, which is not a large amount of time to allow pollen degradation in the arid west. Sample 1, however, exhibits a relatively small pollen concentration, suggesting fairly rapid deposition. Even though radiocarbon ages for samples b and 4 are 1675-1765 AD and 1635-1705 AD, respectively, samples 2, 3, and 4 appear to represent relatively stable surfaces that accumulated large quantities of pollen. Only samples 17, 16, and 15 at the base of this record and sample 9 near the upper portion of Pollen Zone 2 exhibit small pollen concentrations suggesting very rapid sediment deposition. Sample 10 exhibits a fairly low pollen concentration, suggesting fairly rapid sediment deposition.

The pollen record in Profile B is diverse. Quantities of *Pinus* pollen fluctuate widely, peaking in samples 15, 11, and 2. Recovery of large quantities of *Pinus* pollen in the lower three samples (17-15) is not considered unusual because these samples exhibit very low pollen concentrations. The lower portion of the pollen record, perhaps all of Pollen Zone 4, should be viewed with suspicion because these samples contained evidence of modern pollen contamination. Modern *Elaeagnus*, and *Juglans* pollen are recovered from most of these samples and *Sporormiella* dung fungal spores are present in sample 15. Other components of these samples appear more secure.

The base of the pollen record is marked by pollen representing long distance transport, the local pinyon/juniper community, the riparian vegetation community, and a variety of shrubs of the rose family. As pollen concentration increases in sample 14, so do quantities of *Artemisia* and Cheno-am pollen, presenting local sagebrush and saltbush and probably other plants in the Cheno-am group. The Poaceae pollen frequencies are moderately large in these samples and a wide variety of pollen representing riparian plants also was noted. This zone, which represents deposition prior to 4000 BC, appears to represent a time when the riparian community along Rio del Oso included a variety of plants including maple or box elder, a member or members of the umbel family, some chicory-tribe plants, greasewood, sedges, mints, and cattails. Because of the antiquity of these sediments compared to the other records, this zone has been designated Pollen Zone 0.

Sample 13 is the only sample in Pollen zone 1 and might represent a period of transition. The radiocarbon age reported for this sample is BC 3020-2860, but it lies between ages of BC 4060-3915 and BC 3615-3595. The pinyon/juniper community appears to support a sparse stand of trees, although the associated understory community is well developed, including large Cheno-am and *Artemisia* (sagebrush) populations. The riparian vegetation community includes at least *Salix* (willow) and Cyperaceae (sedges). Grasses do not appear to be as abundant. A variety of weedy plants are present including *Salsola*-type, *Erodium*, *Mirabilis*, Onagraceae, and *Sphaeralcea*. The pollen concentration is very high, suggesting a stable surface at this time.

Pollen zone 2 is marked by severe fluctuations in pollen frequencies. Near the base of this zone *Pinus* pollen increases sharply while pollen concentration remains high. At the same time Cheno-am and *Artemisia* pollen decline. This pattern suggests a more dense pinyon/juniper woodland with a less dense population of understory plants. Poaceae pollen is present, but not in as large frequencies as were noted in Pollen Zone 0. Recovery of *Salix* and Cyperaceae pollen indicates that willow and sedges were part of the riparian vegetation community. Both *Euphorbia* and *Sphaeralcea* pollen were present, indicating spurge and globe mallow were present as weedy plants. After the *Pinus* pollen peak in sample 11, *Pinus* pollen declines rapidly. The slight increases in *Juniperus* pollen in the middle of this zone indicate that junipers became more abundant in the pinyon/juniper woodland. *Quercus* pollen increases only after *Pinus* pollen decline, indicating that Gambel's oak became more abundant locally for a short interval prior to BC 1975-1735. *Artemisia* and Cheno-am pollen increase between samples 10 and 8, indicating that sagebrush, saltbush, and other members of the Cheno-am group increased in quantity as the pinyon/juniper woodland thinned. Riparian plants recorded during the upper portion of this zone include Apiaceae, *Sarcobatus*, and Cyperaceae. The absence of *Salix* pollen and presence of *Sarcobatus* pollen suggests increased salinity. Pollen representing weedy plants includes *Salsola*-type, *Erodium*, and *Sphaeralcea*, which appears to reflect a minimum of disturbance. Although

*Cercocarpus* pollen is noted in all samples from this zone, pollen from other shrubs in the rose family was absent.

Pollen zone 3 is represented by a single pollen sample (7), which was not dated. This sample exhibits an increase in *Pinus* pollen, accompanied by a slight increase in *Artemisia* pollen and a decline in Cheno-am pollen. Poaceae pollen remains moderately low. The only pollen representing riparian vegetation is *Sarcobatus*, reflecting alkalinity. *Sphaeralcea* pollen reflects the weedy plant community. This sample appears to reflect a relatively stable surface.

Pollen zone 4 is represented by samples that yielded radiocarbon ages ranging from AD 140-410 to AD 1675-1765. During this interval *Pinus* and *Juniperus* pollen rise slowly to a peak in sample 2. *Artemisia* and Cheno-am pollen maintain moderate levels and High-spine Asteraceae, probably reflecting rabbitbrush and other plant, is observed in its highest frequencies. Pollen representing other understory plants common in the pinyon/juniper community are more abundant and more varied in this zone. Poaceae pollen is more abundant in sample from the base of this zone than throughout most of the rest of the record in this profile. Although pollen representing riparian vegetation is rare in the lower portion of this record, including only *Salix* and Cyperaceae pollen in sample 6, it expands to include *Populus*, *Salix*, Apiaceae, Cyperaceae, and *Geranium* in the upper two samples. Pollen representing weedy plants also is slightly more abundant in samples from this zone and includes *Salsola*-type, *Euphorbia*, Onagraceae, *Portulaca* and *Sphaeralcea.* It is interesting to note that the only evidence for *Portulaca* comes very late in the record. Recovery of *Sporormiella* dung fungal spores in the upper three samples, all of which post-date AD 1635-1705, is consistent with an Hispanic presence and grazing animals such as horses during the historic period. The fungal spore, *Sporormiella*, represent a dung fungus that becomes more abundant in Historic Period sediments following the historic introduction of grazing animals. Its increasing presence in historic samples has been noted in numerous palynological studies (Davis, 1987). *Sporormiella* fungal spores are not confined to the dung of introduced grazers, but also occur in dung from moose, wild sheep, deer, elk, caribou, and rabbits. The increase of *Sporormiella* spores in historic sediments may relate to changing land use patterns and increase in the length of time that herds of animals occupy any given area.

The micro-charcoal record for this profile exhibits the largest quantities of charcoal low in the record, peaking in sample B-13, which yielded a radiocarbon age of BC 3020-2860. Following this time charcoal frequencies decline, then remain moderate until a peak in sample B-6, which returned a radiocarbon age of AD 140-410. In the sample dated to AD 1400-1450 the charcoal frequency was still moderately high, but by AD 1635-1705 it had declined significantly and remains low until the uppermost sample.

The phytolith record for Profile B yields a different zonation than the pollen record. The lowest two samples are broken out in to Zone 0 by cluster analysis. This is followed by samples 15, 14, and 13, which represent Zone 1. During these two zones quantities of buliforms (Figure 6) are generally larger than they are for most of the record, which is consistent with the record from Profile A. the exception occurs in Phytolith Zone 3. In addition, there is a slight increase in festucoid forms and decrease in chloridoid forms, suggesting an increase in cool season grasses and decline in short grasses that prefer hot, dry summer conditions. This combines with the increased quantity of buliforms to indicate well-watered grasses and the probability of an increase in the spring and/or fall growing seasons, perhaps at the expense of the hotter, drier summer. Alternatively, this could have been a period of increased tree and shrub growth along the Rio del Oso, resulting in growth of more shade-tolerant grasses. Phytolith Zone 2 is a period of fluctuations in both festucoid and chloridoid grass short cells. Buliforms are less abundant, in general, than they were in the lower deposits. This zone includes samples that yielded radiocarbon ages of BC 3615-3595, BC 2880-2480, and BC 1975-1735 at the top. Fluctuations in crenate forms of the festucoid group are the most obvious. Taken in the context of reduced quantities of grass short cells in samples B-9 and B-11, this might be a factor of post-depositional dissolution resulting in preservation of the most bulky and thick phytoliths. Grass short cells are less robust than are buliforms and might have been dissolved preferentially in these sediments. Alternately,

this pattern of recovery of elevated crenate forms suggests that a single grass genus might be the cause for most of the variance in this record. *Bromus* is the most notable genus exhibiting crenate forms. Recovery of slightly elevated crescent forms might indicate an increase in needle grasses, which commonly produce this phytolith form. Phytolith Zone 3, which yielded radiocarbon ages of 140-410 AD and 1400-1450 AD in the upper two samples, exhibits large quantities of buliforms in the lower two samples and an increased quantity of volcanic ash fragments relative to the total quantity of grass short cells. The increased quantity of buliforms might be a reflection of dissolution of phytoliths in the sediments because grass short cells comprise a small quantity of the total phytoliths recovered. Sample B-7, which is undated, includes only chloridoid short cells, suggesting near absence of cool season and other grasses. This is unlikely, which lends additional support to the interpretation that these levels suffer from selective dissolution of grass short cells. Phytolith Zone 4 is one of declining festucoid and increasing chloridoid phytoliths, suggesting warming and drying conditions between AD 1635-1705 and AD 1675-1765 or clearing of vegetation along Rio del Oso, resulting in more open areas that supported short grasses in preference to cool season grasses. Cluster analysis indicates close relationships between each of these samples with its nearest neighbor.

### Profile C

The stratigraphic pollen and phytolith records for Profile C are based on six samples. Radiocarbon ages are reported for sample C-7, below the lowest one examined for pollen and phytoliths, at (BC 1040-790), as well as sample C-4 (BC 820-770), and sample C-1 (AD 1020-1210). Cluster analysis of the pollen profile indicates the presence of two zones, which have been labeled 3 and 4 based on radiocarbon ages. Cluster analysis of the pollen profile indicates close relationship between samples C-2 and C-3. Pollen Zone 3 is marked by declining *Pinus* and rising *Juniperus* pollen frequencies (Figure 7), reflecting the local pinyon/juniper community *Quercus* pollen is more abundant than it is later in the profile, indicating that Gambel's oak was a significant member of this woodland community. *Artemisia* pollen is moderately abundant, representing a portion of the local understory. Poaceae pollen is more abundant in Zone 3, suggesting that grasses are more abundant in the local vegetation community. *Zea mays* pollen was recovered in samples C-5 and C-4, again placing evidence for maize agriculture in this area at and before BC 820-770. Pollen zone 4 includes the upper three samples. In general the *Pinus* pollen increases, with the exception of in sample 1, where it is nearly absent and appears to have been replaced by Cheno-am pollen. This suggests tree clearing during the interval AD 1020-1210 and a large increase in the local weedy Cheno-am and/or saltbush populations. Other elements of the local vegetation appear to remain relatively stable. Microcharcoal frequencies peak in sample C-4, which was one of the samples to display *Zea mays* pollen. It certainly is possible that this peak in charcoal coincides to cultural activity.

The phytolith record from Profile C also sorts into two zones by cluster analysis at the same mid-point in the record as the pollen record. Phytolith Zone 3 is marked by slightly declining festucoid forms and slightly increasing chloridoid forms (Figure 8), suggesting slightly warming and/or drying conditions that favor short grasses over cool season grasses. Buliforms are more abundant in Zone 3, as they were in Profile B, suggesting that this was a moderately well watered interval. Phytolith Zone 4 displays fluctuating festucoid and chloridoid short cell frequencies, indicating changing conditions. There is no real pattern to the variation in the phytolith record, which might represent more than 1000 years in these three samples.

## SUMMARY AND CONCLUSIONS

Anthropogenic change to the landscape is not particularly visible in the stratigraphic pollen record along the Rio del Oso. Beginning at or near the base of the pollen record, depending on pollen profile, pollen representing weedy plants is observed regularly. Weedy plants appear to have been part of the natural vegetation, since they are moderately abundant beginning

approximately BC 3020-2860. Land clearing for agriculture, and particularly the aftermath of reforestation following abandonment is very evident in stratigraphic pollen samples examined from Mesa Verde (Cummings 1999; Scott 1973; Wyckoff 1977). This evidence is particularly graphic because of the rapid abandonment of the Mesa Verde area, facilitating rapid reforestation, unhindered by continued human modification of the landscape. No such rebound evidence of reforestation is noted consistently in the pollen record from Rio del Oso. Profile B exhibits very small quantities of *Pinus* pollen between approximately BC 2880-2480 and AD 1735-1705. This is an extremely long period of time and a record that is not substantiated by samples from either Profiles A or C. Therefore, this record is not considered to indicate massive woodland clearing by prehistoric agriculturalists. Evidence for weedy plants abounds in the stratigraphic records beginning around BC 3020-2860 and continues until approximately the AD 1600s to AD 1700s. *Zea mays* pollen was recovered in two of the profiles between BC 1450-1260 and approximately BC 360-280. The paleoenvironmental record can be improved by sampling at closer intervals to provide a pollen record of vegetation at 50-100 year intervals when the sediments support this. This close definition is particularly necessary when addressing anthropogenic change. Close interval sampling within individual strata also helps to clarify the record of vegetation change through time.

Anthropogenic vegetation change is less visible in the phytolith record, which appears to be recording primarily changes in the grass communities in response to temperature and moisture fluctuations through time. To the extent that grasses form part of the weedy plant complex, examination of the horizontal landscape through time (multiple stratigraphic columns sampled at close intervals) would provide a more interpretable data base. The primary changes in the phytolith record probably are related to water level and development of a riparian vegetation community. The stronger the riparian vegetation community, the more festucoid phytolith short cells are expected in the record. The riparian vegetation community appears to have been strongly developed along the Rio del Oso throughout much of the time represented by these stratigraphic records, based on quantities of festucoid short cells recovered from the phytolith records.

TABLE 1
PROVENIENCE OF POLLEN AND PHYTOLITH SAMPLES FROM RIO DEL OSO

| Sample No. | Depth in cm | Description | Conventional Radiocarbon Age (BP) | AD/BC |
|---|---|---|---|---|
| P1V1 | 0 | Veg. type 1, blue grama grassland, some oak, silt, sand, gravel | | |
| P1V2 | 0 | Veg. type 2, juniper with blue grama, silt, sand, gravel | | |
| P1V3 | 0 | Veg. type 3, juniper with some pinyon, silty sand, some gravel | | |
| P1V4 | 0 | Veg. type 4, riparian with cottonwood, willows, juniper, silt & sand, some gravel | | |
| P2V1 | 0 | Veg. type 1, blue grama grassland, some oak, silty, sand, gravel | | |
| P2V2 | 0 | Veg. type 2, juniper with blue grama, silt, sand, gravel | | |
| P2V3 | 0 | Veg. type 3, juniper with some pinyon, silty sand, some gravel | | |
| 100 | 0 | Surface above cut bank | Modern | |
| 200 | 0 | Surface pinch sample at mouth of wash of KU II | Modern | |
| 300 | 0 | Surface, rich organic soil, cryptogamic, same terrace as KU II | Modern | |
| 400 | 0 | Surface north of road | Modern | |
| 24 | 20 | Sand | 640 ± 80 | AD 1250-1435 |
| 23 | 40 | Upper sandy layer | 730 ± 70 | AD 1195-1400 |
| 22 | 60 | Top of organic layer | 950 ± 60 | AD 990-1225 |
| 21 | 90 | Darker organic layer | 1100 ± 60 | AD 800-1030 |
| 20 | 115 | Light sand | 1530 ± 50 | |
| 19 | 150 | Sandy, slightly darker | 1710 ± 80 | AD 135-540 |
| 18 | 175 | Top of thick organic layer | 2120 ± 60 | 360-280 BC |
| 17 | 215 | Bottom, thick organic layer | 3010 ± 60 | |
| 16 | 230 | Possible contamination from upper and lower hearths | | |
| 15 | 240 | | 3110 ± 50 | 1450-1260 BC |
| 14 | 250 | Sandy | 2950 ± 50 | 1295-1000 BC |
| 13 | 260 | Tiny organic layer | 2810 ± 100 | 1260-800 BC |
| 12 | 265 | Sandy | 3140 ± 60 | 1515-1265 BC |

Table 1 (Continued)

| Sample No. | Depth in cm | Description | Conventional Radiocarbon Age (BP) | AD/BC |
|---|---|---|---|---|
| 11 | 280 | Very thin (3 cm) organic concentration | 3510 ± 60 | 1965-1675 BC |
| 10 | 295 | Dark soil, organic, CaC03 | 3570 ± 80 | 2130-1690 BC |
| 9 | 310 | Sandy, few organics | 3800 ± 50 | |
| 8 | 320 | Charcoal, possibly organic | 4230 ± 60 | |
| 7 | 350 | Dark sandy, little or no organics or charcoal | 3760 ± 50 | |
| 6 | 360 | Sandy | 2780 ± 100* | 1200-790 BC |
| 5 | 400 | | 4610 ± 60 | 3515-3285, 3245-3105 BC |
| 4 | 410 | Bottom of dark organic layer w/ charcoal stain | | |
| 3 | 430 | Light organic layer w/ intrusive charcoal from higher layer | | |
| 2 | 450 | same | | |
| 1 | 460 | Sandy | 3540 ± 50* | |
| B-1 | 10 | Silt, fine sand, brown | 30 ± 40 | AD 1675-1765 |
| B-2 | 25-30 | Silt, fine sand, brown | | |
| B-3 | 45-50 | Silt, fine sand, brown | | |
| B-4 | 60-70 | Silt, fine sand, brown | 130 ± 50 | AD 1635-1705 |
| B-5 | 80-90 | Silt & sand, brown | 430 ± 40 | AD 1400-1450 |
| B-6 | 100-110 | Silt & sand, brown | 1660 ± 50 | AD 140-410 |
| B-7 | 125-130 | Chunks of silt, brown | | |
| B-8 | 190-200 | Chunks of silt, brown | 3440 ± 50 | BC 1975-1735 |
| B-9 | 250-260 | Sand | | |
| B-10 | 300-310 | Sand & lumpy silt, lt. brown | 3890 ± 50 | |
| B-11 | 340-350 | Sand & lumpy silt, lt. brown | 4041 ± 60 | BC 2880-2480 |
| B-12 | 370-380 | Sand & lumpy silt, brown | 4560 ± 50 | BC 3615-3595 |
| B-13 | 390-400 | Silt & sand, brown | 4160 ± 60 | BC 3020-2860 |
| B-14 | 550-560 | Silt & sand, lt. brown | 5140 ± 60 | BC 4060-3915 |
| B-15 | 575-585 | Sand | | |
| B-16 | 650-660 | Sand | | |

Table 1 (Continued)

| Sample No. | Depth in cm | Description | Conventional Radiocarbon Age (BP) | AD/BC |
|---|---|---|---|---|
| B-17 | 740-750 | Sand | | |
| C-1 | 90-100 | Silt & sand, brown | | |
| C-2 | 120-125 | Silt & sand, brown | | |
| C-3 | 200-210 | Silt & sand, brown | | |
| C-4 | 230-240 | Silt & sand, brown | | |
| C-5 | 255-260 | Silt & sand, brown | | |
| C-6 | 270-275 | Silt & sand, brown | | |

TABLE 2
POLLEN TYPES OBSERVED IN SAMPLES FROM RIO DEL OSO

| Scientific Name | Common Name |
|---|---|
| LONG-DISTANCE: | |
| *Abies* | Fir |
| *Picea* | Spruce |
| *Pseudotsuga* | Douglas fir |
| PINYON/JUNIPER: | |
| *Juniperus* | Juniper |
| *Pinus* | Pine |
| *Quercus* | Oak |
| *Arceuthobeum* | Dwarf mistletoe |
| P/J UNDERSTORY: | |
| *Artemisia* | Sagebrush |
| Liguliflorae | Includes dandelion and chicory |
| Low-spine | Includes ragweed, cocklebur, etc. |
| High-spine | Includes aster, rabbitbrush, snakeweed, sunflower, etc. |
| Tubuliflorae | Includes eroded Low- and High-spine |
| Caryophyllaceae | Pink family |
| *Cirsium* | Thistle |
| Cheno-am | Includes amaranth and pigweed family |
| *Castilleja* | Paintbrush |
| *Ephedra nevadensis*-type | Mormon tea |
| *Ephedra torreyena*-type | Mormon tea |
| *Eriogonum* | Wild buckwheat |
| *Psoralea* | Scurf-pea |
| *Opuntia* | Prickly pear cactus |
| *Cylindropuntia* | Cholla cactus |
| *Calochortus* | Mariposa, sego lily |
| *Gilia* | Gilia |
| RIPARIAN: | |
| *Acer* | Maple |
| *Alnus* | Alder |
| *Populus* | Poplar |

Table 2 (Continued)

| Scientific Name | Common Name |
|---|---|
| *Salix* | Willow |
| *Ulmus* | Elm |
| Apiaceae | Parsley/carrot family |
| Liguliflorae | Includes dandelion and chicory |
| *Sarcobatus* | Greasewood |
| Cyperaceae | Sedge family |
| Fabaceae | Bean or Legume family |
| *Astragalus* | Milkvetch, rattleweed, locoweed |
| *Petalostemum* | Prairie clover |
| *Galium* | Bedstraw |
| *Geranium* | Geranium |
| Lamiaceae | Mint family |
| *Rhus toxicodendron*-type | Poison ivy |
| Rosaceae | Rose family |
| *Shepherdia* | Buffaloberry |
| *Typha angustifolia* | Cattail |
| WEEDY: | |
| Brassicaceae | Mustard family |
| *Lesquerella* | Bladder pod |
| *Salsola* | Russian thistle |
| *Tidestromia* | Tidestromia |
| *Cleome* | Beeweed |
| *Erodium* | Heron-bill |
| *Euphorbia* | Spurge |
| *Kallstroemia* | Kallstroemia |
| *Linanthes* | Linanthes |
| *Malva* | Mallow |
| Nyctaginaceae | Four o'clock family |
| *Abronia* | Sand verbena |
| *Boerhaavia* | Spiderling |
| *Mirabilis* | Four o'clock |
| Onagraceae | Evening primrose family |

TABLE 2 (Continued)

| Scientific Name | Common Name |
|---|---|
| *Plantago* | Plantain |
| *Portulaca* | Purslane |
| *Sphaeralcea* | Globemallow |
| SHRUBS: | |
| Rhamnaceae | Buckthorn family |
| *Rhamnus* | Buckthorn |
| *Rhus trilobata* | Squawberry |
| Rosaceae | Rose family |
| *Amelanchier* | Service-berry |
| *Cercocarpus* | Mountain mahogany |
| *Holodiscus* | Spirea, ocean spray |
| *Sanguisorba* | Burnet |
| *Viburnum* | Viburnum |
| AGRICULTURAL: | |
| *Zea mays* | Maize, corn |
| HISTORIC: | |
| *Carya* | Hickory, Pecan |
| *Elaeagnus* | Russian olive |
| *Juglans* | Walnut |
| OTHER: | |
| Poaceae | Grass family |
| Asteraceae tissue fragment | Sunflower family |
| *Physalis* seed fragment | Ground cherry |
| Indeterminate | Too badly deteriorated to identify |
| STARCHES: | |
| Solid Starches | |
| Starch with Hilum | |
| SPORES: | |
| Monolete | Fern |
| *Selaginella densa* | Little clubmoss |
| Trilete | Fern |

TABLE 2 (Continued)

| Scientific Name | Common Name |
|---|---|
| *Sporormiella* | Dung fungus |

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